ASSESSING ENERGY AND COST IMPACT OF ADVANCED VEHICLE TECHNOLOGIES

Project ID # VAN023

R. Vijayagopal, E. Islam, V. Freyermuth, N. Kim, A. Rousseau

BACKGROUND & RELEVANCE

- Quantify energy and cost benefits of Vehicle Technologies Office (VTO) R&D targets for light-duty, medium and heavy duty vehicles
- This projects estimates the energy consumption, performance and cost of 30+ vehicle classes/vocations across multiple timeframes, powertrains, component technologies, fuel, duty types and uncertainties.
- The vehicle models and detailed results support numerous VTO funded projects, including:
  - Component technology evaluation
  - SMART Mobility
  - Lifecycle Impact Analysis
  - Market penetration
  - Annual Transportation Technology Baseline (ATB)
  - USDRIVE & 21CTP
- Vehicle assumptions and sizing processes have been updated based on inputs from DOE tech teams and industry partners as well as extensive market data analysis.

PROJECT OVERVIEW

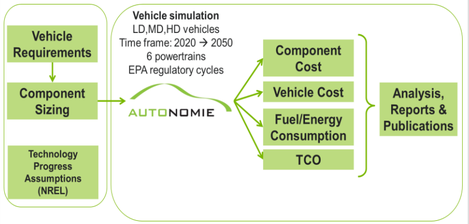
Timeline	Barriers*
• Project start date : Oct FY20 • Project end date : Sep FY22	• Risk aversion • Constant advances in technology • Cost • Computational models, design, and simulation methodologies *from 2011-2015 VTP MYPP
Budget	**Partners**
• Total Funding : $900K • FY20 Funding : $300K • Percent Spent : 60%	Collaborators • Argonne, NREL, ORNL, Sandia Interactions • USDRIVE, 21CTP, DOE, OEMs, suppliers, Autonomie users

OBJECTIVES

- **What are the energy benefits of VTO technologies?**
  - Quantify the petroleum displacement potential of advanced vehicle technologies.
  - Provide energy consumption and cost estimates to market penetration experts.
- **What are the impacts on Total Cost of Ownership (TCO)?**
  - Estimate the vehicle manufacturing costs.
  - Compare the initial investments against fuel/operational cost savings
- **What are the impacts of achieving technology targets?**
  - Compare multiple scenarios over different timeframes (e.g., 2020, 2025, 2030) and uncertainties (e.g., Business as usual vs. DOE/VTO/HFTO targets)
  - Quantify the improvements attributable to DOE program success
- **Who should be the early adopters of new technologies in this domain?**
  - Identify use cases and technologies which
    - Minimize energy consumption
    - Minimize total cost of ownership

APPROACH: ESTIMATE ENERGY ESTIMATION & TCO

- Updated vehicle specifications and powertrain sizing algorithms for the FY21 analysis work.
- Vehicle simulations were carried out on regulatory cycles specific to each type of vehicle.



ACCOMPLISHMENTS: >10,000 NEW VEHICLE MODELS DEVELOPED

LIGHT-DUTY VEHICLES

- New Autonomie vehicle models developed across 5 timeframes, 10 classes, 25 powertrains and 3 uncertainties
- Main updates
  - New torque converter and gearbox performance data (8 to 10 speed cases)
  - Engine scaling process now relates displacement to number of cylinders
  - New component weight and costs (engine, transmissions)

MEDIUM & HEAVY-DUTY VEHICLES

- Over 20 specific class/vocation combinations considered, covering a majority of trucks in the US.
  - **>62%** of the trucks by numbers
  - **>82%** of the truck miles
  - **>90%** of the energy used by trucks
- Specific vocations and body types added to provide more granularity (Eg. Class 6 Box truck & StepVan instead of a generic delivery truck)

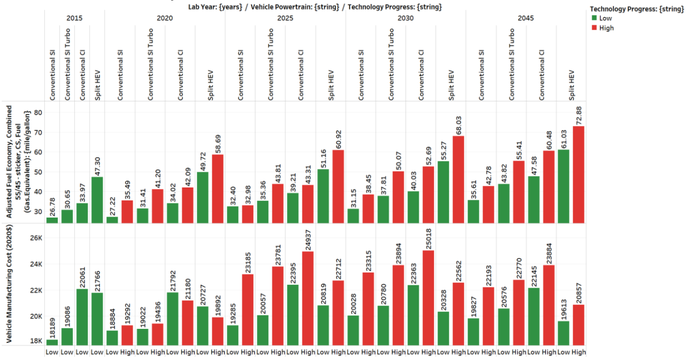
Class	Vocation
2	Van
3	PnD, Van, School, Pickup
4	PnD, WalkIn, Service
5	Utility
6	StepVan, Box, Construction
7	Tractor, Vocational, Van, School
8	Longhaul, Regional, Drayage, Beverage,
8	Refuse, Transit, Vocational

WORKFLOW

- Detailed energy consumption, cost and TCO calculation performed on all vehicles.
- Consistent QA/QC, post-processing and result formats across all classes.
- Extensive use of High Performance Computing (HPC)

ACCOMPLISHMENTS: QUANTIFIED THE IMPACT OF VTO TARGETS ON ENERGY CONSUMPTION, VEHICLE COST FOR LIGHT DUTY VEHICLES

- The preliminary results for midsize vehicles show VTO target goals improve fuel economy of conventionals & HEVs by ~55% - 80%



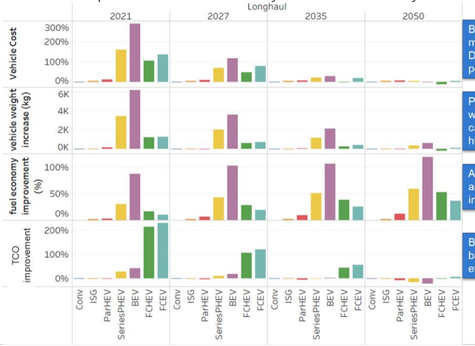
- Autonomie current vehicle show close relations across all parameters of interest among the vehicles with high sales for midsize conventional turbos & HEVs

Model Year	Make	Model	2019-2020 Sales (thousands)*	Engine Disp. (L)	Rated HP	# of Cylinders	Transmission Type	# of Gears	Equivalent Test Weight (kg)	Equivalent Test Weight (lbs.)	Adj UDDS (mpg)	Adj HWFET (mpg)	Combined Adjusted (mpg)	Accel time 0-60mph (s)
2020	HONDA	ACCORD	376	2	252	4	Automatic 10		1644	3625	23	34	27	7.6
2020	Kia	Optima	204	1.6	178	4	Automatic 7		1644	3625	27	37	31	6.9
2020	Ford	Fusion	183	1.5	169	4	Automatic 6		1701	3750	23	34	27	8.9
2020	Hyundai	Sonata	135	1.6	180	4	Automatic 8		1644	3625	27	36	31	7.3
2020	CHEVROLET	MALIBU	102	2	260	4	Automatic 9		1645	3627	29	36	32	8.2
2020	Mazda	Mazda 6	33	2.5	227	4	Automatic 6		1758	3876	23	31	26	7.9
2020	VW	Passat	30	2	174	4	Automatic 6		1700	3748	23	34	27	7.8
MY20 Average		**Midsize**	**220**	**2**	**206**	**4**	**Automatic 6**		**1677**	**3696**	**25**	**35**	**29**	**8**
Autonomie		**Midsize**		**2**	**194**	**4**	**Automatic 6**		**1573**	**3468**	**28.3**	**34.1**	**30.7**	**7.9**

Model Year	Represented Test Veh Make	Represented Test Veh Model	2019-2020 Sales (thousands)*	Engine Disp. (L)	Rated Horsepower	Equivalent Test Weight (lbs.)	UDDS Adjusted (mpg)	HWFET Adjusted (mpg)	Combined Adjusted (mpg)	Battery Voltage, (V)	Battery Energy Capacity, (Amp-hrs)	Motor1 Peak Power (kW)	Motor2 Peak Power (kW)	MSRP** $	0-60mph (s)
2020	TOYOTA	PRIUS		1.798	96	3375	54.5	49.7	52.2	207	4	53	23	26490	9.7
2020	TOYOTA	PRIUS AWD	68.1	1.798	96	3500	52.0	48.1	50.0	202	6.5	53	23	27890	9.7
2020	TOYOTA	PRIUS Eco		1.798	96	3250	57.8	53.3	55.7	207	4	53	23	25280	9.7
2020	Ford	Fusion (HEV)	62.4	2	141	4000	43.0	41.0	42.0	280	4.75	64		29195	9
2020	TOYOTA	CAMRY HYBRID LE	46.9	2.487	176	3750	51.0	52.7	51.8	259	4	88		29425	7.4
2020	TOYOTA	CAMRY HYBRID XLE/SE		2.487	176	3875	44.2	47.0	46.2	259	4	88		33725	7.4
2020	HONDA	ACCORD HYBRID	37.3	2	143	3625	47.8	47.3	47.6	259	4.25	135	104	26425	7.2
2020	HONDA	INSIGHT TOURING	35.9	1.5	107	3375	51.2	44.5	48.0	222	5.5	96		29295	8.1
2020	HONDA	INSIGHT		1.5	107	3250	54.9	48.8	52.0	222	5.5	96		23885	8.1
2020	HYUNDAI	SONATA HYBRID Blue	4.4	2	150	3625	50.0	54.3	51.9	270	5.5	39		28745	6.8
2020	HYUNDAI	SONATA HYBRID		2	150	3750	44.6	50.9	47.2	270	5.5	39		30895	6.8
2020	KIA	Optima Hybrid	1	2	154	3875	39.7	44.9	41.9	270	6.5	38		30235	7.7
	MY20 Average	**Midsize**		**2.0**	**133**	**3604**	**49.2**	**48.5**	**48.9**	**244**	**5.0**	**70**	**43.25**	**28457**	**8.1**
	Autonomie	**Midsize**		**2.0**	**106**	**3611**	**49.7**	**44.7**	**47.3**	**238**	**6.5**	**79.5**	**61**	**32649**	**8.1**

ACCOMPLISHMENTS: ACHIEVING DOE TARGETS WILL ENABLE ELECTRIFIED TRUCKS TO COMPETE WITH CONVENTIONAL TRUCKS IN TERMS OF PERFORMANCE, CARGO CAPACITY AND COST

- Conventional & hybrid long haul trucks will improve fuel economy by 68%-84% by 2050. BEVs will see 72% drop in vehicle price.
- Long haul is among the most challenging use cases for electric trucks. Achieving DOE targets will make BEVs competitive even in this case by 2050. Urban delivery trucks will achieve TCO parity by 2030.



BEVs are about 3 times more costlier to manufacture than conventional trucks, in 2021. Differences in manufacturing cost between powertrains will be negligibly small by 2050.

Present day BEVs have a 6000kg higher curb weight. This results in loss of cargo carrying capacity. This weight penalty reduces to a few hundred kg by 2050.

As electric machines and batteries become lighter and efficient, the fuel economy advantage increases steadily over the years

BEVs will steadily lower cost of ownership, as battery prices drop and vehicles become more efficient.

SUMMARY & PROPOSED FUTURE RESEARCH

- This work quantifies the impact of VTO technologies on energy consumption, performance and cost (MSRP and TCO) across vehicle classes (light to medium and heavy duty vehicles), vocations and timeframes. Uncertainties in technology progress levels are also considered.
- Autonomie models have been developed to represent MY2021 vehicles, including updated assumptions and performance data.
- A consolidated database of vehicle and component cost, mass, component size and energy consumption on regulatory cycles has been developed, and shared with stakeholders. Previous reports available under https://www.autonomie.net/publications/fuel_economy_report.html
- Future research will focus on:
  - Quantifying the value of technology improvement for specific components.
  - This will help prioritize technologies in the order of their energy saving potential

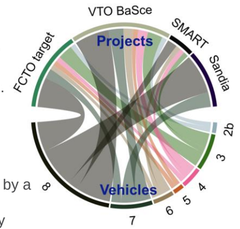
PARTNERSHIPS & COLLABORATIONS

ASSUMPTIONS

- Vehicle requirements were updated based on feedback from 21CTP and USDRIVE partners.
- Component cost were reviewed by experts and DOE tech managers.
- TCO calculations were based on VTO working group (VAN038).

RESULTS

- New vehicle models are shared with other research organizations, automotive manufacturers and suppliers
- Energy consumption, cost and detailed vehicle information are used by a large number of projects (LCA, market penetration, ATB, BNEF…)
- Compiled form of the vehicles developed through this work are freely distributed to support research activities (FOAs, SMART…)



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